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GROUNDWATER RESOURCE OF PAKISTAN AND ITS MANAGEMENT

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SYNOPSIS

The groundwater has been recognized as the third major water resource of Pakistan after the rainfall and snowmelt river surface water supplies. The current decrease in rainfall and reduction in the surface water supplies has created water crisis in the country. Therefore as a Pakistani national it is our duty to collect the detailed information about the third water resource like groundwater potential, quality, exploitation and mining to plan for its management to reduce the problem of water shortage in our country. During a research study by the Groundwater Section of International Waterlogging & Salinity Research Institute (IWASRI) WAPDA, the following useful information about the groundwater resource of Pakistan was collected which may be very helpful for its future utilization and management:

The active flood plains and perennial canal water supply areas in Pakistan contain ground watertable within 30 ft below land surface. Generally it is fresh, potable and fit for human use and crop production. The areas with non-perennial canal supplies possess deep ground watertable generally within 150 ft below land surface containing saline and unfit water for human consumption. The residents of these areas generally depend on the rainwater stored in ponds. Some areas like of Thal Doab have deep good quality water infiltrated from the land surface and standing on impermeable layers. Researchers have revealed that in Pakistan about 66 MAF of groundwater can be used as an additional water resource for crops and human needs after pumping.

The government of Pakistan has been considering the groundwater development seriously since 1960 when Indus Basin Water Treaty was signed with India after the conflict of Indus River Basin Flows utilization between India and Pakistan. According to the Indus Basin Water Treaty, the water of three western rivers i.e. Indus, Jhelum and Chenab was to be used by Pakistan and of three eastern rivers i.e. Ravi, Sutlej and Bias by India. After the implementation of Treaty the three eastern rivers in Pakistan were almost dry as the water was stopped by India. The part of the old irrigation system of the three eastern rivers falling in Pakistan was put in operation by feeding with new link canals off-taking from the western rivers. These link canals were unlined and their seepage resulted in quick rise of groundwater towards land surface causing the problem of waterlogging and salinity in their adjacent areas. Although all efforts were made to continue the old canal irrigation system for irrigation after the Indus Basin Water Treaty but the available link canal water was not enough to feed the whole commands of existing canals. Therefore installation of tubewells was encouraged by government of Pakistan in the private sector especially in the tail reaches of canals where the canal water was insufficient. There was no check on the number of tubewells installed in the private sector. As a result aquifer mining and fresh water scarcity started in most of the areas of tail reaches of canals. It is necessary for the water engineers and Govt. of Pakistan to think seriously about the groundwater management to fight with the current water shortage crisis.

LIST OF ABBREVIATIONS

ACE	-	Associated Consulting Engineers
cfs/msf	-	cubic feet per second per million square feet
ET	-	Evapo-transpiration
FGW	-	Fresh Ground Water
ft	-	foot/feet

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GW	-	Groundwater
IWASRI	-	International Waterlogging and Salinity Research Institute
mm	-	millimeter
MAF	-	Million Acre Feet
NDP	-	National Drainage Programme
NESPAK	-	National Engineering Services of Pakistan
NWFP	-	North Western Frontier Province
PEC	-	Pakistan Engineering Congress
PPSGWP	-	Punjab Private Sector Ground Water Project
PTWs	-	Private Tubewells
SCARP	-	Salinity Control and Reclamation Project
SGW	-	Saline Ground Water
STWs	-	SCARP Tubewells
UNDP	-	United Nation Development Program
WAPDA	-	Water and Power Development Authority

1 INTRODUCTION

1.1 Background

When surface water resource of an area is unable to meet the requirement for its human and crop needs, a search for good quality groundwater is made to meet that requirement by pumpage. Similarly when useful groundwater is found to be in abundance in an area and is economical for use as compared to the surface water, it is preferred over canal water.

The Irrigation System of Pakistan is the largest integrated network in the world which is fed by the waters of Indus Basin (Indus river basin along with its tributaries). Besides its benefits of increase in agriculture production this irrigation system network caused a serious problem of quick rising of ground watertable towards land surface in mid of 19th century. Before the operation of the canal system the ground watertable was quite deep ranging from 50 to 100 ft deep from land surface in the irrigated areas of Pakistan. The overall irrigation efficiencies were 35 to 40 % due to seepage losses from the canals and water courses because the network was unlined. This caused ground watertable to rise @ 0.5 to 1.0 ft per year. As a result the problem of waterlogging and salinity started in the irrigated areas. Government of Pakistan started SCARP programs in 1960 through WAPDA to reclaim the lands from waterlogging and salinity by the installation of tubewells and surface drains. Investigation of groundwater by WAPDA with the foreign and local consultants for these projects reported the existence of a vast useful aquifer in the Indus plain, which was considered as an additional and economical water resource in Pakistan to be used by pumping.

The importance of ground water resource increased when the conflict of Indus River Basin Flows (consisting of six major rivers named as Indus, Jhelum, Chenab, Ravi, Sutlej and Bias along with their tributaries being the common sources of the old combined irrigation system before Indo-Pakistan partition in 1947) utilization started between India and Pakistan after partition. To resolve the conflicts an Indus Basin Water Treaty was signed in 1960 by the Governments of two countries. According to the Treaty, the water of three western rivers i.e. Indus, Jhelum and Chenab was to be used by Pakistan and of three eastern rivers i.e. Ravi, Sutlej and Bias by India.

In Pakistan since 1976, the construction of new reservoirs has not been started until now as a result the surface water supplies remained gradually decreasing due to the sedimentation in the old reservoirs. Therefore most of the surface water users have started pumping of groundwater to complete their water needs without knowing after effects.

The average annual river flow available based on 44 years records (from 1956-57 to 2000-01 financial years) of Government of Pakistan is 157 MAF (NDP, 2001). This water is not sufficient to meet the needs of the irrigated agriculture in Pakistan unless supplemented with the groundwater by pumping in the sweat groundwater zones. The groundwater resource for the entire country of

Pakistan has been estimated to be around 66 MAF and almost the same amount of recharge was recorded from the existing surface irrigation network of the country.

Figure 1 shows map of Pakistan showing groundwater potential areas.



Figure 1 Map of Pakistan showing groundwater potential areas.

1.2 Objectives

The objectives of this technical report are:-

(i) To introduce the importance of groundwater considering it as a third major water resource after rainfall and rivers' surface water supplies.
(ii) To provide a useful and interesting technical information for the experts planning to reduce water crisis in Pakistan.
(iii) To give recommendations for saving of good quality groundwater.

2 REVIEW OF LITERATURE

It is wisely realized that all the storage reservoirs are destined to fill up sooner or later by the sediment brought by the stream on which it is built (PEC, 1994).

In Mohajir Branch of Thal Main Upper Canal 80% of the canal lining was failed after about 15 years of construction due to pressure of high groundwater. The groundwater before the construction of the canal was 40 ft deep but it was raised quickly after the canal construction even the canal was lined (PEC, 1994).

In 1961 the construction of SCARP tubewells was started in Pakistan with the capacity of 2.5 to 3.5 cusecs to be pumped by an imported turbine to pump groundwater at the average depth of 200 feet from land surface. On the protest of the farmers many tubewells were closed in 1962-63 because these were yielding unfit water (PEC, 1994).

Large Scale groundwater development for irrigation has been taking place for the last 20 years through the installation of tubewells both in the public and private sectors. It is estimated that during 1977-78, 27 MAF of ground water was pumped in the canal commands, which constitute about 27% of total irrigation supplies (WAPDA 1981).

Even after the pumpage of Government and Private tubewells there still remains a considerable potential for the development of good quality groundwater in the canal command areas equivalent to about 14 MAF (WAPDA, 1981).

The groundwater resource of entire country was estimated to be around 66 MAF and most of the recharge was from the surface irrigation supplies. The total groundwater resource for each province is 43, 18, 3 and 2 MAF for Punjab, Sindh, NWFP and Balochistan respectively (ACE and Halcrow. 2001).

3 PROVINCE-WISE GROUNDWATER POTENTIAL IN PAKISTAN

3.1 Groundwater Potential in Punjab

The main source of groundwater in the Punjab exists in the four hydro geological zones namely Potohar plateau and salt range, Piedmont areas, Alluvial plains and Cholistan desert. Indus River and its tributaries drain the province. In Punjab a lot of work has been carried out on seepage from the irrigation system and recharge to the groundwater from it (PPSGWP, 1998). The groundwater potential is based on rainfall recharge, groundwater recharge and recharge from irrigation system. The rainfall recharge of 9.90 MAF (15% from 380 mm/year) in different SCARP areas was worked out during the period 1987-97 (PPSGWP, 1998). The recharge from return flow, irrigation application, sub-surface inflows was assessed 7.08 MAF (22.5% of 31.5 MAF). Canal seepage varies from 2 to 8 cfs/msf depending on the size of canal and drainage characteristics. A delivery of 24 large canals for the irrigation year 1990-91 was with an average of 54 MAF. The recharge from these canals was estimated 21.70 MAF (40% of 54 MAF). The recharge from rivers was 3.5 MAF and return flows from domestic & industrial use were assessed as 0.57 MAF (22.5% of 2.52 MAF). The total available groundwater resource of the Punjab Province was estimated 42.75 MAF.

3.2 Groundwater Potential in Sindh

The most important feature is the river Indus, the sole source of surface water for the Province. The groundwater lies in the three hydro geological zones namely Eastern desert (Thar), Western mountain and Indus valleys. The Province useable groundwater is mainly found in the Indus Plain, which is recharged from the meandering river and from the irrigation network that has been developed in the area. The other source of recharge, i.e. rainfall, is quit scanty and its contribution to the resources is limited. Rainfall recharge was 1.96 MAF (2% of 265 mm per year) as worked out by ACE and Halcrow (2001). The recharge from return flows (22.5% of 38.2 MAF), irrigation returns (22.5% of 3.5 MAF) was assessed 8.58 MAF and 0.79 MAF respectively. In the Sindh canal water losses have been taken as 15 % of the total average canals supply of 45 MAF for the period 1988-2000. The recharges from these canals was estimated 6.76 MAF. The recharge from the rivers was assessed 0.3 MAF. The total available resource of the Sindh Province was assessed to be 18 MAF.

3.3 Groundwater Potential in NWFP

The North-West Frontier Province lies in the four broad geological units namely, Metamorphic and igneous rocks of northern mountains, Mesozoic rocks of the southeastern part, Tertiary rocks of the southeastern part and upper Tertiary. The main groundwater resources in NWFP are the alluvial plains and many valleys, which are intermountain basins of tectonic origin. The rainfall recharge was estimated 0.7 MAF (7% of rainfall over a sub catchments). The average flows for the period 1988-2000 was 6.68 MAF (ACE and Halcrow, 2001). In this Province recharges from canal system was worked out 1.0 MAF (15% of 6.7 MAF). The groundwater recharges include returns from irrigation application, other return flows, sub-surface inflows and recharge from rivers. The recharge from the return irrigation flows was assessed 1 MAF (15% of 6.5 MAF) and other return flows (15% of 0.88 MAF) were worked out to be 0.13 MAF. The total groundwater resource of the NWFP Province was assessed as 3.11 MAF.

3.4 Groundwater Potential in Balochistan

The regions of the Province, which are underlain by unconsolidated sediments, formed by the deposition of mountainous outwash from the surrounding highlands, have been divided into 12 distinct Basins, flood plains and valleys fills. The Province lies in the five hydrological zones namely, Mountain ranges, Piedmont plains, Valley floor, Players and Rolling sand plains. The groundwater in substantial quantity occurs in unconsolidated aquifers in almost all basins and sub-basins. The groundwater resources were assessed by WAPDA and re-assessed by ACE and Halcrow (2001). They re-assessed the groundwater resources in six basins of the province namely Hamune, Lora, Kachhi plain, Nari, Pishin and Zhob. The effective rainfall coefficient of 20% to the annual rainfall for the mountain areas is used to estimate rainfall of 1.21 MAF. In Balochistan canal supplies are small in total and restricted to the south of the Province, adjacent to Sindh Province. For the period 1988-2000 the average canal flow was 1.94 MAF and recharge from these canals was assessed as 0.29 MAF (15% of 1.94 MAF). Other components of groundwater recharge include return flows from irrigation application, other return flows, sub-surface inflows and recharge from rivers. The recharge from return flows of irrigation application was estimated 0.37 (22.5% of 1.62 MAF) and other return flow was 0.08 MAF (20% of 0.45 MAF).The total groundwater resource of Balochistan Province was assessed as 2.13 MAF.

4 GROUNDWATER EXPLOITATION

Because of the existing of high permeable aquifers in most of the Indus Plain, it is possible to extract water easily and also to store large quantities of water (Hafeez, 2002). Use of tubewells for pumping groundwater for irrigation was started by Irrigation Department Punjab, soon after independence. However, large-scale development of groundwater (tubewells technology) for irrigation started in 1958 by WAPDA through its salinity control and reclamation programme. As a result it was picked by the private sector and large installation of private tubewells took place. The exploitation of groundwater in the four Provinces of Pakistan is complicated due to a number of natural and man-made factors. The numbers of tubewells have been increased from 2700 in 1950 to over 600,000 in the year 2000-2001 (Table 1). The numbers of users are over 2.5 million farmers, who exploit groundwater through their own tubewells or hire from their neighbors. Their behavioral patterns are highly variable and they understand little about any adverse interaction, which is likely to result due to unsystematic and erratic nature of groundwater exploitation.

In Punjab, the importance of groundwater can be justified from the fact that quantitatively it is contributing to the tune of over 50% of canal water supplies available at the farm-gate. canal system provides about 55 MAF of water to Punjab each year. Of this amount approximately 40% recharge goes to the groundwater. This recharge and additional irrigation water is provided through groundwater extraction. Presently there are about 500,000 Private Tubewells in the province abstracting 30 MAF to cover an area of 51 MAC. Discharge of the Private Tubewells varies from less than 0.5 cusecs to more than 1.5 cusecs and operation factor ranges from about 3% to more than 30% with an average of 10.5%. Additional groundwater 4 MAF is extracted for SCARPs,

industrial and domestic use. In Sindh province, presently a small component of potential groundwater resources is being exploited by public and private tubewells. Total groundwater extraction is about 3.5 MAF, which includes pumpage by 25,000 private tubewells and 4100 SCARP tubewells. Groundwater of NWFP province has been studied by M/S ACE & Halcrow in 2001. According to this study only a small percentage of the exploitable groundwater resource has so far been developed by dug-wells, tubewells or otherwise. In this Province, the existing groundwater abstraction through 13000 private and 491 public tubewells is 2 MAF per year. According to the study on private tubewells carried out by NESPAK in 1991, the average capacity of these tubewells is 0.6 cusecs and their utilization varies from 24 to 27 percent. The groundwater in the Balochistan province has been studied at the time of WAPDA-UNDP investigations in the province. It has been estimated that at present groundwater abstraction of 0.45 MAF by about 24000 private tubewells, the average capacity is 0.3 cusecs, 0.18 cusecs of pumped dug wells and 0.0005 cusecs for karezes/springs (ACE and Halcrow, 2001).

Table 1 Number of Private Tubewells in all Provinces

Year	Growth of Private Tubewells in Pakistan									
	Punjab		Sindh		NWFP		Balochistan		Pakistan	
	Number	Annual Increase	Number	Annual Increase	Number	Annual Increase	Number	Annual Increase	Number	Annual Increase
1965	28746	6790	2977		331		470		32524	9384
1966	36217	7471	3069	92	446	115	650	180	40382	7858
1967	44488	8271	3161	92	615	169	870	220	49134	8752
1968	58797	9309	3253	92	773	158	1075	205	58898	9764
1969	62034	9237	3345	92	966	193	1285	210	67630	8732
1970	75646	13312	3437	92	1163	197	1870	585	8181	14186
1971	81814	6468	3531	94	1488	320	2278	408	89106	7290
1972	90844	9080	4359	828	1645	162	2521	243	99369	10263
1973	99674	8870	5187	828	1695	50	3040	519	109596	10267
1974	109293	9619	5996	809	1709	14	3646	606	120644	11048
1975	130453	21160	6380	384	2735	1027	4262	616	143831	23197
1976	134782	4329	6600	220	3254	518	4631	369	149267	5436
1977	140724	5942	6734	134	3312	58	4863	232	155633	6366
1978	144121	3397	8590	1856	362	314	5143	280	161480	5847
1979	147995	3874	9016	426	4252	426	5954	811	167217	5587
1980	154468	6473	11253	2237	4292	40	6453	499	176466	9249
1981	161867	7399	12992	1739	4364	72	7033	580	186256	9790
1982	166361	4494	14305	1313	4493	129	7458	420	192612	6356
1983	171264	4903	15017	712	4568	75	7691	238	198540	5928
1984	187754	16490	15435	418	4685	11	7997	306	215871	17331
1985	205253	17499	16028	593	4746	61	7887	110	233914	18042
1986	213408	8155	16028		4772	26	7952	85	242160	8246
1990	272200	14698	17500	368	7000	557	11000	762	307500	16335
1995	406000	26760	19000	300	9000	400	17000	1200	451000	28700
2000	500000	18800	25000	2000	13000	800	24000	1400	562000	22200

Source: ACE and Halcrow, 2001.

The overall water balance is actually comprised of certain recharge and discharge components. The details of these components with relevance to the groundwater system of four provinces are given below (Table 2). The difference between yearly recharge and discharge of an

aquifer can be used as an initial guide to the sustainable groundwater development of the groundwater reservoir.

The groundwater potential for the Sindh province is 14.91 MAF; the additional sustainable groundwater deployment is worked out as 10.32 MAF of groundwater (ACE and Halcrow, 2001), consisting of 3.52 MAF from the fresh groundwater zones and 6.80 MAF from saline groundwater zones. Approximately 65% of these developments potential are located in the Rohri (FGW) and Nara (SGW) canal commands.

Table 2 Groundwater Balance for all four Provinces

Parameters	Punjab (MAF)	Sindh (MAF)	NWFP (MAF)	Balochistan (MAF)
Recharge Component				
Rainfall Recharge	9.90	1.96	0.87	1.21
Recharge from Canal System	21.70	6.76	1.00	0.29
Return flow from irrigation	7.08	8.58	1.02	0.37
Domestic and industrial return flows	0.57			
Other return flows		0.79	0.13	0.08
Recharge from Rivers	3.50	0.30	0.13	0.18
Total	**42.75**	**18.39**	**3.15**	**2.13**
Discharge Components				
Groundwater Abstraction (Private, STWs and PTWs)	31.50	3.49	1.77	0.45
Groundwater Abstraction (domestic and industrial)	2.50			
Non-beneficial ET losses	8.75	13.75	0.24	1.13
Sub-surface Outflow/change in GW			0.90	0.41
Baseflow to Rivers		1.15	0.24	0.14
Total	**42.75**	**18.39**	**3.15**	**2.13**

Source: ACE and Halcrow, 2001.

From the water balance in Table 2 it can be seen that the total groundwater resources for NWFP are 3.15 MAF. About 1.77 MAF of groundwater is being extracted. However, when the only available figures for other discharges from the Province are taken into account it would appear that the Province is in deficit. The ACE and Halcrow, (2001)'s report clearly stated that groundwater resources should be developed step-wise so that any unforeseen change in behavior of the aquifer could taken into account in the next development stage.

Table 2 reveals that groundwater resources for Balochistan are 2.13 MAF. About 0.45 of groundwater is being extracted. This indicates that a groundwater potential of 1.69 MAF is more available for the Province. However, 0.67 MAF of that potential resource is linked to the canal system in the south of the Province. The remaining potential for the rest of the Province is 1.02 MAF. The sustainable groundwater development in the Province is 0.64 MAF (ACE and Halcrow, 2001), with 50% of this potential located in two basins of Porali and Hingol. The situation has worsened in a number of sub-basins since 1996 as the uncontrolled development of groundwater in the Province was allowed to continue. Some sub-basins within the Province (Quettea, Mastung, Mangochar and Pishin in the Pishin-Lora basin, Loralai, and Duki in the Nari basin) are rapidly approaching a catastrophic state in terms of its groundwater resources and urgent action is needed to prevent.

5 GROUNDWATER MANAGEMENT

Because of the absence of the groundwater management over 8% of the groundwater exploitation is taking place in the country. In the private sector anyone can install a tubewell

anywhere in his land and can extract whatever amount of water he wants any time without consideration of the detrimental effect of his action on the resource. If the pumping is equal to recharge rate for a sufficient period of time, the watertable depth will stabilize somewhere below the ground surface. In case the pumpage of groundwater is in excess to the potential recharge rate, the mining of the aquifer will result in the accelerated depletion of the groundwater resource with an unsustainable lowering watertable. Also the uneven groundwater development and pumping through private tubewells has started showing stress on the aquifer in the form of excessive drawdowns and deterioration of groundwater quality. This requires serious attention of govt. of Pakistan to adopt measures for the proper groundwater management.

In Pakistan irrigation system was designed for very low cropping intensities, but with population pressure, the actual intensities become manifold than the design. The difference between crop water requirement and canal supplies are met through exploitation of groundwater. The ground watertable data of the last 15 years indicates that out of 43 canal commands, watertable is depleting in different canal commands.

Continuous over-draft in access of the average annual recharge has been resulting in the knocking out shallow pumping wells. More pumping in relatively dry years like nowadays is causing excessive draw down in certain areas. As a result at present about 5% area of Punjab Province and 15% of Balochistan contains the groundwater, which is out of the reach of the poor farmers. This is likely to increase to 20% in Punjab and 30% in Balochistan in the next 25 years with the present growth of groundwater withdrawals and unsystematic pumping in fresh groundwater due to abnormal lowering and areas adjoining saline zones. Figure 2 shows trend of annual private tubewell increase in Pakistan from 1965 to 2000.

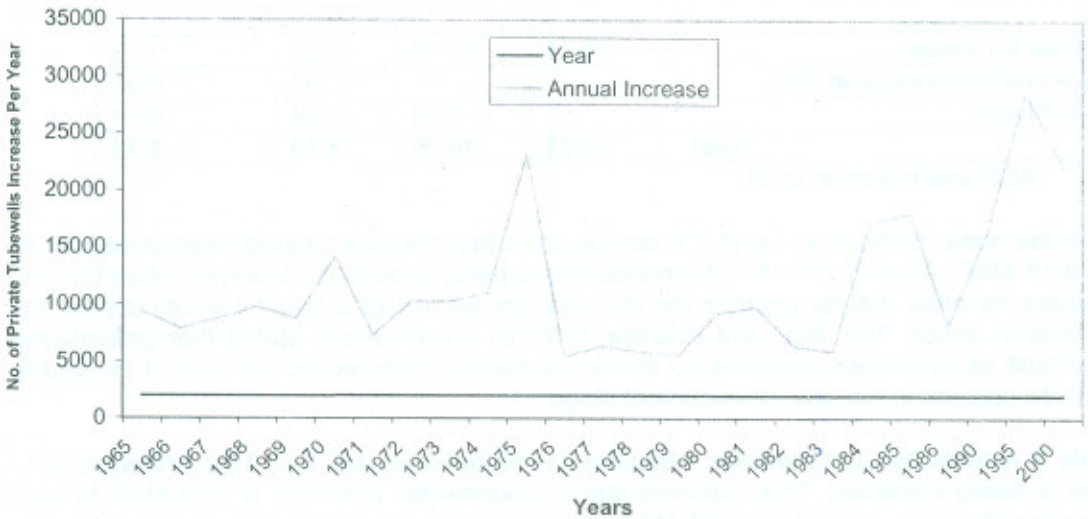


Figure 2 Graph Showing Trend of Private Tubewell Increase in Pakistan

6 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

1. Groundwater is the third important water resource of Pakistan after rainfall and snowmelt river supplies. The groundwater resource of entire country has been estimated to be

around 66 MAF and most of the recharge is from the surface irrigation supplies. The province-wise total available groundwater resource is about 43, 18, 3 and 2 MAF for Punjab, Sindh, NWFP and Balochistan respectively.

2. In the private sector anyone can install a tubewell anywhere and can extract desired amount of water any time without consideration of the detrimental effects of the action on the national shared water resources.

3. Installation of turbines for pumping of deep groundwater affected the shallow water table quality from good to bad and also reduced the soil fertility in the areas where these were installed.

4. Continuous withdrawal of ground water without recharge in shallow water zones may result tubewell drying.

6.2 Recommendations

1. Groundwater being the third important resource of water if utilized properly and wisely can easily help to reduce the water shortage problem of Pakistan.

2. The groundwater management should be improved. There should be check and a balance for pumping of groundwater to prevent its misuse, mining and problem creation for the others. Mere pumping may not be allowed and the existing regulations of equal share of pumping and fixed minimum allowable distance between two tubewells in an area should be strictly followed. Government of Pakistan may revise these regulations with the severe punishments of imprisonment or fines.

3. In good quality shallow water zones only centrifugal pumps should be allowed instead of turbines for pumping so that deep saline water shouldn't be mixed.

4. Government agencies working in the villages of shallow water zones must advise the farmers about limited pumping in the shallow watertable zones so that the limited fresh water may not be finished.

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